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GAO (GENERAL ACCOUNTING OFFICE) ASSESSMENT OF DOD'S
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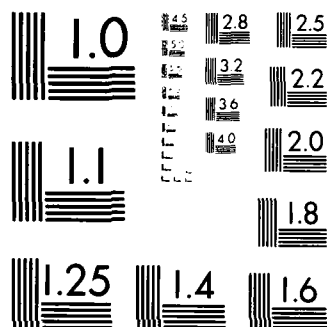
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Report To The Secretary Of Defense

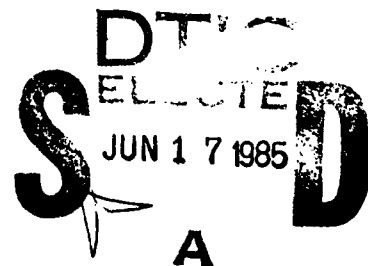
GAO Assessment of DOD's Very High Speed Integrated Circuits (VHSIC) Technology Program

GAO reviewed DOD's Very High Speed Integrated Circuits (VHSIC) program--an effort to develop and demonstrate advanced data and signal processing technology for defense systems. Although progress has been made, the development, demonstration, and independent verification of first generation VHSIC technology is behind schedule. Nevertheless, DOD believes that VHSIC technology must be used in defense systems and in 1982 expanded the program to promote near-term system applications.

In light of the delays and other problems, GAO is concerned with DOD's decision to further expand subsidies to stimulate earlier application of VHSIC technology. To achieve the goals of the program, GAO believes that DOD should emphasize progress goals for already approved contractor subsidies and the demonstration and independent testing of first generation VHSIC technology.

This report discusses the expansion of the program, as well as the status of its original objectives, and recommends alternative ways for DOD to encourage system developers to promptly consider using VHSIC technology.

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

NATIONAL SECURITY AND
INTERNATIONAL AFFAIRS DIVISION

B-215788

The Honorable Caspar W. Weinberger
The Secretary of Defense

Dear Mr. Secretary:

We have reviewed the Very High Speed Integrated Circuits (VHSIC) program--a high priority Department of Defense (DOD) effort initiated in 1981 to develop and demonstrate two generations of advanced data and signal processing (integrated circuit) technology for defense systems. Although technical progress has been made, the six companies under contract to DOD have found the development and demonstration of first generation VHSIC technology to be more difficult, expensive, and time consuming than anticipated.

DOD decided in 1982 to expand the program beyond its original objectives--to develop and demonstrate new technology--by providing direct subsidies to the six VHSIC contractors, and to defense system developers within the military departments to actively promote the use of first generation VHSIC technology in defense systems. This program expansion was undertaken to expedite the use of VHSIC technology to insure that the nation can maintain a competitive edge over our adversaries through superior electronic equipment. DOD's decision to expand the program increased the total estimated program costs from \$339 million to \$781 million.

There is evidence that DOD and the VHSIC contractors have encountered significant delays and other problems in developing, demonstrating, and verifying the first generation VHSIC technology. Because of these problems, we have concerns about DOD's emphasis on program expansion before the technology has been fully developed and tested.

DEVELOPMENT AND DEMONSTRATION
OF THE FIRST GENERATION VHSIC
TECHNOLOGY ARE BEHIND SCHEDULE

In 1981, six companies received contract awards to develop and demonstrate first generation VHSIC technology. Those contracts involved the design and fabrication of several different kinds of VHSIC chips, initial testing of the technical adequacy of the individual chip designs, and demonstration of the chips in a brassboard prototype (i.e., subsystem configuration).

The contractors were expected to consistently produce technically acceptable VHSIC chips. However, as of December 1984, only about half of the 29 proposed VHSIC chip types have been produced, and most of those in limited quantities. In addition, only one contractor had completed the required demonstration of the brass-board prototype, and several contractors may not be ready to do so until late 1985--some 18 months behind the scheduled completion date of May 1984.

Plans have been made to conduct independent tests to verify that the VHSIC chips produced to date meet performance and other key requirements. However, initial testing has been limited to independent tests of VHSIC chip components (test chips) and to observations by DOD officials of the testing done by the VHSIC contractors.

To reach informed decisions about the incorporation of new technologies such as VHSIC in advanced system designs, system developers need to know whether the technology meets or exceeds their technical requirements, is cost-effective, and has no major risks. Although DOD believes that most, if not all, first generation VHSIC technical objectives will be attained, that achievement may not be demonstrated and verified for several years. We believe that emphasis on the completion and independent testing of first generation technology could increase the early utilization of VHSIC technology without further program expansion.

EXPANSION OF VHSIC PROGRAM

Originally projected to cost about \$339 million, the VHSIC program is now expected to cost \$781 million through fiscal year 1989, and proposals under consideration could lead to program costs in excess of \$1 billion. (See app. I.) Most of the cost increases result from DOD's decision to expand the program's scope beyond its original mandate--to develop and demonstrate technology--to actively promote the application of VHSIC technology in defense systems at the earliest possible date. About 2 years before the contractors were scheduled to complete the development and demonstration of first generation VHSIC technology, DOD started to implement an expanded program of subsidies that includes

- a \$192 million yield enhancement and manufacturing technology initiative to increase the quantity and reduce the cost of VHSIC chips produced by the contractors, and
- a \$148 million technology insertion initiative (proposed for expansion to \$210 million) to increase the near-term demand for VHSIC chips by system developers.

The remaining increase of \$102 million relates to increased funding for first and second generation technology and for computer aided design.

Yield enhancement and manufacturing technology initiative

In 1982, DOD became concerned that the six contractors might be reluctant to maintain and/or improve their chip manufacturing capabilities because the anticipated demand for VHSIC chips by system developers could be slow to materialize. Through its yield enhancement and manufacturing technology initiative, DOD proposed to improve, with direct subsidies, the contractors' manufacturing efficiency so that reasonably priced VHSIC chips would be widely available as soon as possible.

A \$102 million yield enhancement subsidy, started in fiscal year 1984, is supporting the continued operation and general enhancement of the VHSIC contractors' pilot production lines. DOD's goals are to (1) increase the contractors' manufacturing yield--the percent of technically acceptable chips of the total chips produced--from initial estimates of less than 2 percent to 10 percent, and (2) decrease the unit cost of VHSIC chips from the initial estimates of about \$5,000 to about \$500 by 1987.

An additional \$90 million manufacturing technology subsidy, which DOD plans to start in fiscal year 1985, will address specific equipment-related problems the six contractors are encountering in producing, assembling, and testing VHSIC chips.

Historically, price competition and commercial market forces have been a powerful impetus for improving manufacturing efficiency and reducing costs in the integrated circuit industry. Currently, in an effort to stay competitive with DOD's VHSIC contractors, over a dozen other major defense contractors and integrated circuit suppliers are making significant investments to develop their own VHSIC-manufacturing capabilities independently from the VHSIC program and the DOD subsidies. One of the difficulties inherent in the use of subsidies for market intervention is the absence of information about what the market would do without the subsidies. For example, DOD has projected that, without subsidies, VHSIC chip unit costs would be reduced from the initial estimates of about \$5,000 to about \$1,500 by 1987. This reduction is expected to occur as a normal course, as continuing contractor work and investments improve their VHSIC chip manufacturing efficiency. DOD stated in its comments on our draft report that the additional cost reductions to \$500, which it estimated would be stimulated by further subsidized manufacturing improvements, would result in significant savings to the government. However, the assumptions about demand on which the estimates are based have not been achieved to date, and it is uncertain whether the subsidies will have the full cost reduction effect in light of the schedule and production problems which are occurring in the development and demonstration effort.

The yield enhancement subsidies were initiated by DOD before the six contractors completed their original contractual obligations to develop the chip manufacturing techniques necessary to achieve consistent and cost-effective yields of VHSIC chips. In our draft report, we proposed that DOD make continued yield enhancement subsidies contingent on each contractor's demonstration of progress toward meeting the 10 percent yield and \$500 unit cost goals for VHSIC chips by 1987. DOD agreed and has established yield enhancement progress goals. DOD plans to make continued subsidies contingent on the contractors' attaining those goals.

DOD also will establish, where applicable, progress goals for the \$90 million manufacturing technology initiative, and plans to make continued subsidies contingent on their attainment.

Technology insertion initiative

In 1982, DOD also became concerned that defense system developers might be reluctant to promptly commit to using VHSIC technology because of the inherent technical and cost risks associated with any technology emerging from development. Through the technology insertion initiative, DOD wants to increase the demand for VHSIC chips by encouraging the consideration of the technology in defense systems through subsidized development of near-term system applications. The subsidies are being used in most cases to offset some of the costs system developers would normally incur in designing and building a VHSIC-based prototype for evaluation and comparison with a prototype based on other integrated circuit technology.

DOD has committed \$148.2 million so far for 38 potential system applications, such as missiles and communication equipment. (See app. II.) DOD plans to provide \$62.2 million more in subsidies for an as yet undetermined number of potential system applications beyond the 38 already identified.

DOD believes that an effective level of VHSIC application in defense systems can be attained only through a subsidized technology insertion initiative. However, no criteria have been established for the number of subsidies which are necessary or the schedule of utilization of VHSIC technology which is appropriate. DOD is drafting a policy directive on when and how system developers should consider using VHSIC technology. According to VHSIC program officials, such a directive would probably not mandate the use of VHSIC technology, but would require that it be fully and seriously considered for use in defense systems.

We believe that the expedited issuance of a policy directive would encourage system developers to promptly consider using VHSIC technology without first receiving subsidies. Moreover, increased emphasis on efforts to fulfill the VHSIC program's original

mandate to develop, demonstrate, and verify VHSIC technology would minimize system developers' uncertainties about using VHSIC technology. In the absence of criteria for the appropriate number of subsidies or schedule of utilization, there is no evidence that an expansion of the subsidy program beyond the 38 systems already identified is necessary or desirable.

RECOMMENDATION

We recognize that the yield enhancement/manufacturing technology initiatives are well under way and we support DOD's recent efforts to establish and enforce progress goals for these initiatives. Given the substantial additional investment already made in manufacturing improvements and technology insertion initiatives, and in the absence of criteria for identifying the desirable number of technology insertion subsidies to achieve specific program objectives, we recommend that you not approve the additional \$62.2 million planned for VHSIC technology insertion subsidies. Instead, we recommend that you

--complete the development, demonstration, and verification of first generation VHSIC technology, and

--issue the proposed policy directive on when and how system developers should consider the use of VHSIC technology.

AGENCY COMMENTS

DOD provided extensive comments on the findings and conclusions in our draft report. The comments, for the most part, did not dispute the facts represented in our report, but did present an alternative interpretation of some of those facts and a more optimistic assessment of program progress. Because of the range of issues addressed in DOD's comments, we have expanded our report to provide additional context for the discussion.

DOD stated that it believes that VHSIC technology must find its way into defense systems and, to make that happen more expeditiously, it was necessary to expand the VHSIC program in order to expedite the availability of VHSIC chips, to reduce their unit cost, and to increase the near-term demand for them. To that end, DOD disagreed with our recommendation that the additional \$62.2 million in technology insertion subsidies be disapproved.

While we concur in the desirability of the goal to expedite the availability of VHSIC chips and to reduce their cost, we do not agree that further expansion of technology insertion subsidies is warranted in the absence of clear criteria for the achievement of program objectives. We believe that expanded use of VHSIC technology would be facilitated by reemphasis on the original program goals of development, demonstration, and independent verification of first generation VHSIC technology, and by DOD guidance

on the desirability of considering VHSIC-based alternatives for near-term system applications.


Additional details on our review are included in appendix I. DOD's comments on the draft of this report appear in appendix III.

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As you know, 31 U.S.C. 720 requires the head of a federal agency to submit a written statement on actions taken on our recommendations to the Senate Committee of Governmental Affairs and the House Committee on Government Operations no later than 60 days after the date of the report. A statement is also to be submitted to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report.

Copies of this report are being sent to the above Committees; the Chairmen, Senate and House Armed Services Committees; the Director, Office of Management and Budget; the Secretaries of the Army, the Navy, and the Air Force; and other interested parties.

Sincerely yours,


Frank C. Conahan
Director

GAO ASSESSMENT OF DOD'S
VERY HIGH SPEED INTEGRATED
CIRCUITS (VHSIC) TECHNOLOGY PROGRAM

INTRODUCTION

The Very High Speed Integrated Circuits (VHSIC) program is a high priority, Department of Defense (DOD)-wide effort managed within the Office of the Secretary of Defense (OSD). The VHSIC program's primary objectives are to develop and demonstrate two generations of advanced data and signal processing technology, with strong emphasis on the specific, demanding, and often unique needs of current and future defense systems. In the late 1970's, DOD found that commercial manufacturers were not producing, on a timely basis, the kinds of integrated circuit chips that would be most useful in defense systems. Most manufacturers were concentrating on chips with the greatest commercial potential, such as microprocessor and memory chips, which were not designed to survive the rigors of the military environment. In addition, state-of-the-art technology was not being used to build the militarized chips that would provide near-real-time signal processing capability--the key to substantially more effective defense systems. DOD believed a separate technology development and demonstration effort was necessary to stimulate VHSIC development because individual defense system development programs did not have the necessary resources and leverage to carry out such an ambitious and costly venture.

DOD expects each subsequent generation of VHSIC technology to provide timely and cost-effective opportunities to significantly improve defense system performance, reliability, and maintainability while being less of a burden to the systems in terms of power, weight, and space. DOD has already identified key areas for potential VHSIC application, such as cruise missiles, military satellites, fire and forget missiles, radar, command and control, wideband data communications, undersea search, electronic warfare, and signal intelligence.

OBJECTIVES, SCOPE AND METHODOLOGY

We evaluated the VHSIC program because of the significant increases in program costs and congressional concerns. In reports on approved DOD authorization and appropriation requests, the Congress expressed concerns about the program's objectives, structure, and costs, as well as about the dissemination of VHSIC technology. We held extensive discussions with VHSIC program officials in OSD and the military departments, with the six participating contractors, with various other DOD officials, and with other defense contractors. We reviewed key program documents,

including the development contracts and progress reports. Our review was made in accordance with generally accepted government auditing standards and was conducted from May 1983 to August 1984.

DEVELOPMENT AND DEMONSTRATION
OF FIRST GENERATION VHSIC
TECHNOLOGY ARE BEHIND SCHEDULE

In 1981, six contractors received awards to develop first generation VHSIC technology,¹ to design and fabricate several different kinds of VHSIC chips, and to demonstrate applications of those chips in subsystem brassboard prototypes.² All six contractors encountered difficulties in the design and initial production of their proposed VHSIC chips. As of early December 1984, only about half of the 29 proposed VHSIC chips types had been successfully produced and initially tested and most of those in relatively limited quantities. Some of the remaining VHSIC chip types may need extensive design changes to be producible in even limited quantities.

Although the contractors were making technical progress, it became evident to DOD early in the program that the original cost and schedule allowances would very likely be exceeded. In order not to overrun the contract prices, DOD directed the contractors to give priority attention to those activities leading up to the brassboard prototype demonstrations. Other tasks in the original contracts, such as preliminary research on second generation technology, that were not deemed essential to the brassboard demonstrations were deemphasized or removed entirely. Nonetheless, only one VHSIC contractor was able to demonstrate its brassboard prototype by the originally scheduled date--May 1984. Two other contractors were expected to demonstrate their prototypes in early 1985, or about 8 months behind the original schedule. However, the remaining three contractors were not expected to demonstrate their prototypes until late 1985--some 18 months behind schedule.

Commenting on our draft, DOD reported that technical progress has been made and stated that a conscious decision had been made to use available VHSIC program funds to increase the near-term demand for VHSIC technology--the technology insertion initiative (see p. 10)--rather than trying to recover the original development and demonstration schedule of each participating contractor. DOD stated that the difficulties in design and pilot production were risks associated with every leading edge technology

¹Separate contracts were awarded by DOD in late 1984 to develop and demonstrate second generation VHSIC technology.

²An operating assembly for engineering evaluation purposes.

development and that the VHSIC contractors would complete their tasks at their own expense, albeit with a stretchout of the schedule. However, DOD's yield enhancement initiative (see p. 7) is focused directly on the major problems that have negatively affected the contractors' schedules for developing and demonstrating VHSIC technology--the design and initial production of first generation VHSIC chips.

DOD has focused considerable attention on the subsystem brassboard demonstrations in order to demonstrate that VHSIC technology is a feasible alternative for defense system applications. We believe that such demonstrations are important but should not be viewed as the only indicator of viable performance in a military environment. Additional demonstrations and verifications of VHSIC technology, although planned and in process, are not yet complete. For example

- Although work is planned at DOD laboratories, independent organizations, and the VHSIC contractors' facilities to ensure that all military requirements are satisfied, DOD has not yet independently verified that the VHSIC chips produced to date fully meet established performance, survivability, testability, and reliability requirements. Independent testing so far has been limited to VHSIC chip components (test chips), and to observations by DOD officials of the testing done by the VHSIC contractors. Since defense systems are expected to rely heavily on the advanced capabilities of VHSIC chips, independent verification that military requirements for complete VHSIC chips have been met is an important program milestone.
- Programs have been planned at various DOD laboratories to formally certify that VHSIC chips meet stringent military qualification standards. However, military-qualified VHSIC chips may not be widely available for several years, and near-term system application opportunities currently under discussion may have to depend on VHSIC chips that have had limited independent testing. The largest impediment is that there are not enough of each VHSIC chip type available for the certification process. Other problems that have affected this process include the lack of adequate test equipment and the need to modify the existing certification process in light of the specific characteristics and relatively high cost of VHSIC chips.
- A key program objective has been to make VHSIC technology readily available to all system developers as soon as possible for their evaluation and potential use. Although preliminary technical information has been made available and system application workshops are being held, access to the current VHSIC chips or to the design facilities necessary to create new VHSIC chips is still relatively

restricted. Access is expected to improve as additional quantities of VHSIC chips are produced and as the technical maturity of those design facilities improves. The availability of VHSIC chips (even on a sample basis) and design facilities will have a direct impact on the extent and timeliness of VHSIC system applications.

DOD believes that substantial progress has been made and that next, if not all, first generation VHSIC technical objectives will be attained. To gain system developer acceptance of VHSIC technology, we believe DOD needs to emphasize the prompt fulfillment of the primary program objective--the development, demonstration, and independent verification of VHSIC technology.

EXPANSION OF VHSIC PROGRAM

Originally, DOD expected the VHSIC program to cost about \$339 million. Currently, the program is projected to cost at least \$781 million through fiscal year 1989 and possibly in excess of \$1 billion. (See table on p. 5.) About \$350 million has been obligated through fiscal year 1984.

Although the cost of the overall VHSIC program has irrationally increased, the cost increases have been related primarily to additional tasks undertaken in the program. Commenting on our draft report, DOD stated that those additional tasks had been considered absolutely essential to maintain America's competitive edge over its adversaries through superior electronic equipment.

Most of the additional tasks, as well as most of the increase in the program's costs, can be traced to DOD's decision in 1982 to expand the program's scope. DOD projects that this expansion will ultimately cost as much as \$400 million--more than twice the cost of the first generation VHSIC technology development and demonstration phase. In expanding the program, DOD established new objectives--to promote the near-term application of first generation VHSIC technology in a wide range of defense system acquisition programs, and to improve the VHSIC contractors' manufacturing capabilities. The original program mandate called for technology development and demonstration but no direct DOD role in promoting the application of VHSIC technology to defense systems. Although the original mandate is not yet fully achieved, the program's primary focus has shifted as DOD sought to accelerate the process of putting advanced integrated circuit technology into defense systems as rapidly as it emerged from industry.

DOD was concerned that system developers would not make a prompt commitment to using first generation VHSIC technology because of any new advanced technology's inherent cost and technical risks. In addition, because the demand for first generation technology may be slow to materialize, DOD was also concerned that

DOD Funding for VHSIC Technology

<u>Funding categories</u>	<u>DOD funding estimates</u>		
	<u>Original^a</u>	<u>Current^b</u>	<u>Proposed^c</u>
	----- (millions) -----		
First generation technology:			
Definition studies	\$ 10.5	\$ 10.5	\$ 10.5
Development and demon- stration phase	167.8	165.5	195.5
Yield enhancement and manufacturing technology initiative	-	192.0	192.0
Radiation hardening activities	-	17.0	57.0
Military qualification activities	-	10.0	30.0
Packaging activities	-	1.7	11.7
Technology insertion initiative	-	148.2	210.4
Subtotal	<u>178.3</u>	<u>544.9</u>	<u>707.1</u>
Second generation technology:			
Definition studies	-	11.3	11.3
Development and demon- stration phase	83.6	73.0	150.0
Lithography development	-	9.9	9.9
Subtotal	<u>83.6</u>	<u>94.2</u>	<u>171.2</u>
Other:			
Design automation development	-	62.2	62.2
Various research projects	36.8	40.0	40.0
Management and support	40.0	39.6	39.6
Subtotal	<u>76.8</u>	<u>141.8</u>	<u>141.8</u>
Total	<u>\$338.7</u>	<u>\$780.9</u>	<u>\$1,020.1</u>

^aFunding profile as of May 1981.

^bDOD approved funding profile as of February 1984.

^cFunding requirement identified by the VHSIC director as of February 1984.

--Military qualified VHSIC chips will be widely available within the next few years. As described above, steps toward military qualification are proceeding apace so that the qualification process can be completed as soon as possible. Yield enhancement will help ensure that sufficient quantities of VHSIC chips are available for the qualification process and the growing number of system applications.

GAO ANALYSIS

DOD's comments were helpful in pointing out that some defense system contractors are now getting access to some of the current VHSIC chips and to some of the VHSIC design facilities. We have made adjustments to reflect this information. Other than that, DOD's comments do not dispute but instead confirm the information presented in our draft report. However, DOD's comments include numerous projections of anticipated events, rather than depictions of actual events, and go beyond the information presented in our draft report. In addition, we would note that (1) several of the system applications referred to by DOD are being subsidized by the VHSIC program and (2) we had not previously heard of any DOD plans to use less than perfect VHSIC chips.

o FINDING D: Program Should Focus on Demonstration of First Generation VHSIC Technology. GAO found that first generation VHSIC technology has not yet been fully and convincingly demonstrated. GAO concluded that the VHSIC program should focus priority attention on this before moving on to the development and demonstration of second generation VHSIC technology. GAO stated that DOD has the opportunity to make adjustments in the program including delaying or reducing the planned expansion of the program.

DOD Nonconcur

Comment: Full and convincing demonstration of first generation VHSIC technology, including brassboard demonstrations, has been completed at IBM. TRW and Honeywell will complete brassboard demonstrations in 1984. The other three have fully and convincingly demonstrated the 1.25 micrometer chip technology. During 1985, it is reasonable to expect that all will have successfully completed the original requirements of Phase 1. During Phase 1 all of the contractors have demonstrated a patterning capability for making submicron devices at low logic complexity and are fully prepared to proceed into Phase 2. Several companies have already demonstrated 0.5 micron technology with complexities up to several thousand gates.

Although DOD is unquestionably focusing high priority attention upon providing full and convincing demonstration of the usefulness of the first generation of VHSIC technology, it would be a critical mistake not to maintain our technological momentum by

Surveillance Measures Direction Finding Location and Intercept (MEDFLI) (non-VHSIC) contractor in order to utilize their chips in RPV-based ELINT systems. The TRW brassboard will also be demonstrated in 1984. Other Phase 1 contractors are completing their tasks at their own expense, albeit with a stretch-out of the schedule. A conscious decision was made to apply available funds for technology insertion rather than trying to recover the original schedule at every contractor. The difficulties in design and pilot production is a risk associated with every leading-edge technology development.

---Over 2000 VHSIC chips of 13 different chip types have been produced. Several more chip types will be fully functional within the next month or two, resulting in the majority of chip designs being fully functional. For example, two more chip types from TRW are nearly fully functional. They contain minor errors which are easily correctable and even early prototypes are useful for numerous applications. Yield enhancement has also already begun to bear fruit. Early runs of some of the more complex chips have had encouraging yields (i.e., greater than one percent). For example, IBM has completed its first yield verification runs and significantly raised the percentage yield of its yield enhancement test chip, the Signal Processing Element (SPE) chip. This chip is a simplified version of the Complex-Multiply-Accumulator (CMAC) and based on early success, it appears likely that the VHSIC objectives will be exceeded.

---All completed VHSIC chip types have been tested in contractor facilities with DOD personnel surveillance. In-house chip qualification programs have been instituted at laboratories throughout DOD. DOD is presently independently verifying the surmountability and reliability of VHSIC chips. In addition, some independent testing was performed with test chips even before the first VHSIC chips became available. Additional work is planned at several laboratories, independent organizations and at the VHSIC contractors' plants to ensure that all military requirements are met.

---Not only do contractors have access to some of the new technology, but they are already making good use of them. For example, E-Systems, a non-VHSIC contractor has received several TRW chips and is already evaluating their use in an Air Force program. TRW is making available matrix switch chips at their own expense to all qualified DOD requesters. Honeywell has received TI's 3K x 9 Static Random Access Memory chips and is planning to use them for a Navy application. More VHSIC technology is being made available as sufficient quantities are developed. Moreover, design tools such as Hughes' design aid are being made available to all qualified requesters. TI has distributed to 47 requesters the design software developed under its VHSIC contract.

found the funding requirement identified by the VHSIC director is over \$1 billion.

DOD Concurs

Comment: Although the cost of the overall VHSIC program has dramatically increased since its inception, these cost increases have primarily been related to additional tasks undertaken by the program. These tasks are considered absolutely necessary to achieve the overall goal of the VHSIC program: to maintain America's competitive edge over its adversaries through superior electronic equipment.

o FINDING C: Other Problems. GAO found problems other than cost growth. These include GAO's findings that:

- The VHSIC brassboard prototype demonstrations (operating assemblies of subsystems using VHSIC chips -- for engineering evaluation) are from 15 to 18 months behind schedule,

- less than half of the different kinds of VHSIC chips to be produced have, so far, been produced, and these only in limited quantities,

- DOD has not yet independently verified the performance, survivability, testability, and reliability of VHSIC chips,

- although preliminary technical information is being made available, contractors other than the six VHSIC contractors do not have direct access to the current VHSIC chips or to the design facilities necessary to create new VHSIC chips,

- military qualified VHSIC chips may not be widely available for several years.

DOD Nonconcur

Comment: All of the Phase 1 VHSIC contractors have made very significant progress on the programs. For example: IBM demonstrated its brassboard on 1 May 84 as scheduled. They are currently in joint negotiation with a major non-VHSIC defense contractor to use their VHSIC chips in the Army Mast-Mounted Helicopter sight. Honeywell has fully demonstrated their complete VHSIC chip set. They are currently incorporating these chips into the Army Bandwidth Reduction and Intelligent Target Tracker (BRIT) program for Remotely Piloted Vehicle (RPV) infrared (IR) surveillance, and are negotiating with a major (non-VHSIC) defense aircraft frame contractor for incorporation into the LHX aircraft. Their brassboard will be completed by the end of this year. TRW has fully demonstrated two thirds of their chips and is currently using these chips to upgrade the Air Force ALQ-131 (EW pod). They are also currently working with the Army Miniaturized Electronic

brassboards were to be demonstrated in Phase 2. As stated by the 1982 Defense Science Board (DSB) report on Optimal Planning and Execution of DoD Very Large Scale Integration (VLSI) Activities; "The greatest risk in the VHSIC program, in our judgement, is not that we will fail to achieve the technical objectives, but that we will make a sluggish or incomplete implementation of the technology." The expanded Technology Insertion program was then formulated and included by the Congress in the FY84 appropriation. The DSB recommendation was made to encourage direct interfaces between the VHSIC technology developers and DoD system developers, including funding of early development efforts by the VHSIC program. This arrangement has already made significant progress toward providing successful demonstrations of actual application of the VHSIC technology, thereby attesting to its credibility.

The expansion of the VHSIC program beyond its original aims was deemed necessary to insure that the technology which was being developed and demonstrated in Phase 1 would be available and reasonably priced to enhance the chances of inserting the technology into military systems in a timely manner.

DOD does not concur that utilization of this emerging technology was unexpectedly slow. If possible, system developers do not unconditionally commit their programs to a new, emerging technology. That commitment must be coupled with a lower risk technology in order not to jeopardize program costs and schedules. This is particularly true for systems that are already beyond the concept development stage. In fact, the response to VHSIC technology has been extremely enthusiastic by any measure; in response to DOD requests for candidate systems for insertion of VHSIC technology, the Services nominated more than 100 systems and Service program offices have matched DOD VHSIC funds committed to the candidates selected for insertion by 2:1.

DOD also does not concur that a determination had not been made that anticipated demand would necessitate full production capability by all six contractors. The preliminary outputs from the technology insertion program show a demand for chips from all the VHSIC Phase 1 lines. If the program is as successful as initial responses suggest, there will be a demand for the full production capability at the 10% yield from all pilot lines. As GAO noted, over 100 technology insertion opportunities were recommended by the Services. There is a large market. Each VHSIC contractor chip set is being utilized in DOD systems, and it is imperative that all six contractors establish an efficient pilot line production capability to provide technology alternatives to system designers and to provide competition in future system procurement.

FINDING B: Cost Increases. GAO found that, originally, DOD expected the VHSIC program to cost about \$339 million, whereas it is currently budgeted at about \$781 million through FY 1989. GAO

GAO DRAFT REPORT DATED OCTOBER 3, 1984
(GAO CODE No. 951788) - OSD CASE No. 6621

"IS THE EXPANSION OF DOD'S VERY HIGH SPEED INTEGRATED
CIRCUITS (VHSIC) PROGRAM NECESSARY?"

DRAFT DOD RESPONSE TO GAO DRAFT REPORT

FINDINGS

o FINDING A: VHSIC Program Going Beyond Original Aims. The GAO found that the Very High Speed Integrated Circuits (VHSIC) program is a DOD wide effort to develop and demonstrate two generations of advanced integrated circuits (ICs) designed for application in a wide range of defense systems. GAO found that, mid-way through the program, DOD is concerned that utilization of this emerging technology has been unexpectedly slow. GAO found that, as the program was originally structured, VHSIC funding support was limited to the demonstration of pilot production facilities. However, in order to stimulate demand, the VHSIC program is now assuming the role of promoting first generation VHSIC technology by: (1) spending \$192 million to improve manufacturing efficiency by supporting continued operation at all six VHSIC contractors pilot production lines while upgrading these contractors' VHSIC manufacturing technology; and (2) subsidizing design, engineering and prototyping in a large number of defense systems development programs, at a cost of \$210 million. GAO also found that a determination had not been made that anticipated demand would necessitate the development of full production capability by all six contractors. Although GAO has reservations about the need to expand the program in this way, it recognizes that there is broad interest within DOD and the Congress in getting VHSIC technology into defense systems as soon as possible. It also recognizes that this expansion is already underway and it concludes that cancelling this expansion could significantly destabilize the program.

DOD Partially Concurs

Comment: DOD concurs that the VHSIC program has gone beyond the original aims. As the GAO found, the VHSIC program is a DOD wide effort to develop and demonstrate two generations of advanced integrated circuits designed for application in a wide range of defense systems.

Recognizing that technology evolving from the VHSIC program must ultimately make its way into fielded systems, the question arose, "How can the process be accomplished most expeditiously?" The original VHSIC program planning documents and Phase 1 contracts called for brassboard demonstrations to prove the applicability of VHSIC to solve real, military system problems. There



RESEARCH AND
ENGINEERING
(R&E)

THE UNDER SECRETARY OF DEFENSE

WASHINGTON DC 20301

9 NOV 1984

Mr. Frank C. Conahan
Director, National Security and
International Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

This is the Department of Defense (DOD) response to your letter of 3 Oct 1984 which transmitted your Draft Report (GAO Code No. 951788) entitled, "Is the Expansion of DoD's Very High Speed Integrated Circuits Program Necessary?" (OSD Case No. 6621).

The primary objective of the Very High Speed Integrated Circuits (VHSIC) Program is to accelerate the process of getting integrated circuit (IC) technology into DoD weapons systems as rapidly as it emerges in the IC industry, regaining the ten-year lead the U.S. formerly had over its adversaries.

The GAO report questions the pace and progress of the program, and in particular the need for the expansion of the program in areas of yield enhancement, manufacturing technology, and technology insertion. DoD should continue its aggressive pace in this program. The technology developments of Phase 1 are proving beneficial in numerous system applications and the successful fabrication of submicron circuitry provides a strong foundation for proceeding with submicron technology development.

Detailed DoD comments, which address each of the findings and recommendations contained in the draft report, are provided in the attachment to this letter. These comments will answer GAO's questions regarding the progress of the program and the decisions of the VHSIC Program Office. The opportunity to comment on this report in draft form is appreciated.

Sincerely,

James P. Wade, Jr.
James P. Wade, Jr.
Act. Sec.

Attachment

DEFENSE SYSTEM APPLICATION EFFORTSSUBSIDIZED BY THE VHSIC PROGRAMARMY

- Precision Location Reporting System/Joint Tactical Information Distribution System - Hybrid
- Mast Mounted Sight for Army Helicopter Improvement Program
- TOW Wireless Command Link
- Airborne Signal Processor for Light Experimental Helicopter
- Firefinder Radar Processor
- Hellfire Fire and Forget Missile
- Copperhead Conventional Microprocessor Improvement
- M1 Tank Target Acquisition and Fire Control Processor
- TOW Automatic Target Tracker
- Advanced High to Medium Altitude Air Defense Missile
- Short to Medium Range Air Defense Missile

NAVY

- Enhanced Modular Signal Processor
- MK 50 Torpedo
- AN/UYS-1 Sonar Signal Conditioner
- F/A-18 Airborne Radar Programmable Signal Processor
- AYK-14 Standard Airborne Computer
- Extremely High Frequency/High Frequency Communications Terminal
- Submarine Advanced Combat System-Bus Interface Unit
- High Speed Anti-Radiation Missile - Low Cost Seeker Processor
- Link Moss (Classified Program)

AIR FORCE

- AN/ALQ-131 Electronic Warfare Pod
- Launch and Leave Guided Bomb
- Common Signal Processor
- Military Standard 1750A General Purpose Computer
- Future Fighter Avionics Demonstration/Pave Sprinter
- Improved Modular Radar Warning Receiver
- Automatic Target Recognizer
- Advanced Onboard Signal Processor
- Military Strategic, Tactical and Relay System - Modem Processor
- Speech Processor
- Advanced Air-to-Surface Missile
- Infrared Search and Track System
- Extremely High Frequency Satellite Adaptive Array Processor
- Automatic Test Equipment
- AN/ALQ-131 Phase 2
- Logistics Retrofit Engineering
- Radar Array Controller
- Air-to-Air Missile Advanced Processor

developers to utilize VHSIC technology without subsidies, we question whether \$62.2 million more in subsidies will produce the desired results. Therefore, we do not believe that DOD should further expand its subsidies to additional system developers.

DOD plans to issue policy
directive on VHSIC technology

We were informed by VHSIC program officials that in order to enhance the prospects for the wider use of VHSIC technology, DOD was drafting a policy directive on when and how defense system developers should consider using VHSIC technology. According to VHSIC program officials, the proposed directive would probably not mandate VHSIC technology use but would, after a specified date, oblige system developers to rigorously consider using VHSIC technology as a prerequisite to DOD approval for the acquisition program to transition to its next phase (full-scale development, production, etc.). These officials said that system developers would presumably be required to provide the rationale for a decision not to use VHSIC technology. In our view, expediting promulgation of this directive would encourage defense system developers to promptly and seriously consider the costs and benefits of using VHSIC technology without first receiving subsidies.

nominated by the military departments, an average technology insertion subsidy of about \$3.8 million will be paid by the VHSIC program.

Most system developers are
unwilling to use VHSIC
technology without subsidies

In early 1983, DOD asked the military departments to nominate system acquisition programs for VHSIC technology insertion subsidies. The military departments promptly responded with listings of more than 100 candidate programs. The magnitude of this response demonstrates that system developers have a keen interest in VHSIC technology and that numerous system applications may ultimately be possible. However, only a few system developers have made a commitment to use VHSIC technology without subsidies. In addition, in most subsidized system applications, there is a commitment by the system developer only to evaluate and compare a VHSIC-based system design to a system design based on an alternative integrated circuit technology. There is no certainty that the developer will select the VHSIC-based system design. VHSIC officials recognize that they do not have enough resources to subsidize all the potential applications already nominated by the military departments. Most, if not all, of the \$148.2 million currently budgeted for the technology insertion initiative has been committed to the 38 system applications already approved.

Questionable need for additional
technology insertion funding

DOD stated that the use of VHSIC technology would potentially provide such substantial benefits to defense systems that increased subsidies--the additional \$62.2 million proposed for the technology insertion initiative to allow additional defense systems the benefit of evaluating VHSIC technology--will be money well spent. DOD added that the additional customer base provided by the additional \$62.2 million subsidy would create more competition at the system level.

We are concerned that there are no criteria for the optimum number of technology insertion subsidies to achieve the system application program goal. Since the 38 system applications already subsidized should clearly demonstrate the applicability of VHSIC technology to a broad range of defense systems, we do not see the need for DOD to subsidize additional system applications for the same purpose. In addition, it is unclear to what extent these additional insertion subsidies are expected to encourage other system developers to promptly consider and potentially use VHSIC technology without subsidies--the key underlying justification for the technology insertion initiative. Since the \$148.2 million in technology insertion subsidies already committed to system applications has apparently not encouraged other system

the chip manufacturable at higher yield should not be excluded and that those circumstances were under DOD's control.

DOD did not dispute our finding that some VHSIC chips, as currently designed, may require considerable effort to produce even in limited quantities. Since it was our previous understanding that DOD was not going to permit the contractors to make major design changes in their proposed VHSIC chips, we were concerned that the contractors might spend considerable time and effort working on hard-to-produce chips, without changing their designs, and less time on generic VHSIC chip producibility problems. We believe that DOD should encourage the contractors to promptly make such design changes where necessary.

Our draft report questioned the use of yield enhancement subsidies for those product improvements necessary to meet the basic VHSIC performance, reliability, and survivability requirements. We believe these concerns will be minimized since DOD agreed to make yield enhancement progress payments contingent upon the contractors' demonstration of progress toward meeting the VHSIC chip yield and unit cost goals by 1987.

VHSIC technology insertion initiative

Concerned that system developers might be reluctant to promptly use VHSIC technology in their systems because of the inherent technical and cost risks associated with this emerging technology, DOD decided in 1982 to establish the technology insertion initiative in order to increase the near-term demand for VHSIC technology. By subsidizing VHSIC-oriented design, engineering, and prototyping activities in selected defense system acquisition programs, DOD's goal was to demonstrate as soon as possible that VHSIC technology could be effectively used in defense systems applications. DOD expected that this approach would encourage other system developers to adopt VHSIC technology to their systems without first receiving subsidies.

DOD initially planned to spend, through fiscal year 1989, about \$143.2 million for the technology insertion initiative. About \$30 million has been obligated through fiscal year 1984, and the director of the VHSIC program has identified a funding requirement for an additional \$62.2 million for the technology insertion initiative.

In most cases, the technology insertion subsidy is being used to offset some of the costs system developers would normally incur in designing and building a VHSIC prototype for evaluation and comparison with a prototype that features more conventional integrated circuit technology. Acquisition program funds will finance the remainder of the cost associated with such efforts. For each of the 33 programs selected to date (see app. II) from those

ambitious goals. The yield enhancement effort was not originally structured to ensure that the VHSIC contractors were committed to achieving these goals in the timeframe designated. DOD initially did not require that the contractors guarantee achievement of any specific level of VHSIC chip yield enhancement or cost reduction or make any additional corporate investments to improve their chip-manufacturing efficiency. For example, some contractors were having problems in the initial production of certain VHSIC chips because of particular features of their design and/or their relatively large size. These contractors were not precluded from using the yield enhancement subsidies to continue working on such problems, even though the problems may be unique to those individual chips. In addition, DOD believes that product improvements, such as those necessary to meet the basic VHSIC performance, reliability, and survivability requirements, are an appropriate use of the yield enhancement subsidies. To the extent that these subsidies are used for purposes other than developing generic VHSIC chip design and manufacturing process improvements, we are concerned that DOD may not achieve its VHSIC chip yield and unit cost goals by 1987.

Assuming that DOD will continue its yield enhancement subsidies, we proposed in our draft that more definitive requirements be levied on the VHSIC contractors to help ensure that their efforts to increase the manufacturing yields and reduce the unit costs of VHSIC chips are successful. We proposed that continued yield enhancement subsidies be contingent on each contractor's demonstration of progress toward meeting the 10-percent VHSIC chip yield and \$500 unit cost goals by 1987. Progress can be measured because DOD has adequately provided for periodically determining the contractors' manufacturing yields. While this proposal would not guarantee that the DOD yield enhancement subsidies would be used exclusively for generic improvements in the manufacturing efficiency of VHSIC chips, it should minimize the extent to which the subsidies are spent by the contractors on problems unique to individual VHSIC chips.

DOD agreed to our proposal and has established yield enhancement progress goals, consistent with the 10-percent goal. Subsidy progress payments are planned to be made based upon attaining these goals. In addition, the work statements for the manufacturing technology initiative contracts to be awarded in fiscal year 1985 will contain yield objectives, where applicable, on which progress payments will be based. However, DOD stated that improvements in integrated circuit yields had typically been realized through changes in chip design as much as through improvements in the chip-manufacturing process. DOD also stated that prohibition of improvement in specific chip designs would unnecessarily restrict the progress of the yield enhancement effort because chip design and layout changes can reduce the chip size and the need for even tighter control of the chip-manufacturing process. DOD stated that minor design rule changes which make

efficient production capabilities for all six contractors. If DOD's projection of a large future demand for VHSIC chips is reasonable, the six contractors might have pursued full production capabilities without additional DOD subsidies. The emergence of at least a dozen other potential suppliers of VHSIC chips who are making large corporate investments--estimated to be \$50 million to \$100 million--appears to be an additional incentive for these contractors to pursue manufacturing improvements. Under these circumstances, DOD subsidies for improved VHSIC chip-manufacturing efficiency appear unnecessary. On the other hand, should the future demand for VHSIC chips not be as large as expected--as some VHSIC officials suggested during our review--there may be no need for DOD to sponsor development of full production capabilities for all six contractors.

Historically, price competition and commercial market forces have been a powerful impetus for improving manufacturing efficiency and reducing costs in the integrated circuit industry. One of the difficulties inherent in the use of subsidies for market intervention is the absence of information about what the market would do without the subsidies. For example, DOD has projected that, without subsidies, VHSIC chip unit costs would be reduced from the initial estimates of about \$5,000 to about \$1,500 by 1987. This reduction is expected to occur as a normal course, as continuing contractor work and investments improve their VHSIC chip manufacturing efficiency. DOD stated in its comments on our draft report that the additional cost reduction to \$500 which they estimate would be stimulated by subsidized manufacturing improvements, would result in significant savings to the government over the life cycle of VHSIC technology utilization. However, the assumptions about demand on which the DOD estimates are based have not been achieved to date, and it is uncertain whether the subsidies will have the full cost reduction effect in light of the schedule and production problems which are occurring in the first generation development and demonstration effort.

DOD plans to tie yield enhancement
subsidies to contractor progress
toward meeting yield and cost goals

While we do not believe that there was a clear need for DOD to implement the program to improve the manufacturing efficiency of the six VHSIC contractors, we recognize that there is a broad consensus among DOD and the Congress in getting VHSIC technology into production as soon as possible and that the producibility of VHSIC chips will be a primary concern in reaching that goal. Thus, the yield enhancement effort is already under way, and it would be disruptive and possibly counterproductive to suspend or curtail it at this time.

Our estimate, assuming VHSIC chip yields to at least 10 percent and chip unit costs to about \$500 by 1987 are

defense systems. We believe that DOD can make great strides toward meeting that objective by reemphasizing the completion of the development, demonstration, and verification of first generation VHSIC technology.

VHSIC yield enhancement and
manufacturing technology initiatives

As is common in the initial production of state-of-the-art integrated circuits, the manufacturing yields³ of VHSIC chips are relatively low and unit costs are quite high. DOD believes that VHSIC chips will not be widely used in defense systems until their availability and unit costs are significantly improved. Therefore, DOD intends to spend about \$192 million in fiscal years 1984-87 for its yield enhancement and manufacturing technology initiative. Of this total amount, \$102 million is to subsidize the continued operation of the six VHSIC contractors' pilot production lines and \$90 million is to upgrade their manufacturing technology. About \$39 million was obligated for these purposes in fiscal year 1984.

DOD wants to ensure that first generation VHSIC technology will be available and reasonably priced in order to enhance the chances of inserting the technology into defense systems in a timely manner. Through the ongoing yield enhancement effort, DOD has established the goal of improving, by 1987, its six contractors' manufacturing yields from the initial estimates of 0.5 to 2 percent to better than 10 percent for all VHSIC chips on a sustained basis. In addition, DOD has set a goal of reducing VHSIC chip unit costs from initial estimates of \$5,000 per chip to about \$500 per chip. DOD's yield enhancement subsidies--\$102 million--are being used primarily to support the continued operation of the VHSIC contractors' production lines at specific minimum rates for 32 months. Manufacturing efficiency is expected to improve as the contractors accumulate production and testing experience.

The \$90 million manufacturing technology initiative, which DOD plans to start in fiscal year 1985, will consist of an extensive series of projects directed primarily at improving the equipment used in the production, assembly, and test of VHSIC chips.

It is desirable for DOD to encourage the VHSIC contractors to establish efficient production capabilities. However, it is unclear whether enough is known about the future demand for VHSIC chips to have justified DOD's subsidizing the development of

³The total number of technically acceptable chips expressed as a percentage of the total number of chips manufactured.

the VHSIC contractors may not aggressively maintain and/or improve their manufacturing capabilities. Consequently, DOD implemented a two-pronged expanded program of subsidies that included

- a \$192 million yield enhancement and manufacturing technology initiative (see p. 7) to increase the quantity and reduce the cost of VHSIC chips produced by the six contractors and
- a \$148 million technology insertion initiative (which may increase to \$210 million--see p. 10) to increase the demand for VHSIC chips by system developers.

Commenting on our draft, DOD concurred that the VHSIC program had gone beyond its original mandate. But DOD stated that the technology evolving from the program must ultimately make its way into fielded defense systems and that the key question is how that process could be accomplished most expeditiously. DOD referred to the 1982 Defense Science Board report on VHSIC, which concluded that the greatest risk to the VHSIC program was the possibility of a sluggish or incomplete implementation of the technology rather than a failure to achieve its technical objectives.

The study leading to the Defense Science Board report was conducted in late 1981, well before the schedule and other problems in developing and demonstrating VHSIC technology became evident. In addition, the report did not discuss whether system developers should make commitments to use VHSIC technology before the attainment of its technical objectives has been demonstrated and verified. The Board report did, however, express somewhat similar concerns to ours by stating that:

"...There is a danger of early overkill. By pushing hard for VHSIC applications before many chip designs are completed, before successful chips have been fabricated and reliability assured, and certainly long before the first chips will become available, the program is accepting a high-risk high-payoff strategy. The risk is that promises will be made but not fulfilled, that systems will be committed to VHSIC chips that cannot be delivered on schedule, and that the political and technical communities will react adversely. The payoff is early insertion, perhaps fully justifying the risk because of its value...."

Our concern is that although it may be appropriate for DOD to pursue a high-risk high-payoff strategy for a limited number of near-term system applications, DOD needs to redirect its attention on reducing, as soon as possible, the level of technical and schedule risk inherent in inserting VHSIC technology in a large number of

beginning the development of Phase 2 submicrometer technology in parallel with the completion of Phase 1 verification and demonstration. The highly successful IC industry typically supports three concurrent activities:

- maintaining production (yield enhancement/manufacturing technology),
- transitioning technology into products (technology insertion), and
- development of next generation (submicron technology) VHSIC.

In that industry, a new generation of commercial IC products emerges every 2 to 4 years. The VHSIC program is an effort to match that pace in applications unique to military needs. The successes achieved in Phase 1 have borne out the validity of the VHSIC approach.

VHSIC is aimed at regaining the 10-year lead the U.S. formerly had over our adversaries in the area of electronics. It is now time to move forward toward providing the additional capabilities achievable through the use of submicrometer dimensions in order to preserve our technological lead. Delaying parts of the program runs counter to the reasoning which led to initiation of the VHSIC program, and to Congressional action in 1982.

GAO ANALYSIS

In our draft report, we did not intend to suggest that the development of second generation VHSIC technology be considered an expansion of the VHSIC program or that it be delayed or reduced. Our position is that DOD should concentrate on completing the development, demonstration, and verification of each successive generation of VHSIC technology and not on subsidizing early system applications of those technologies before completing their development, demonstration, and verification.

o FINDING E: DOD Should Rely on Competition Rather than Additional Funding to Improve VHSIC Manufacturing Efficiency. GAO found that the original VHSIC contract called for the development of manufacturing techniques necessary to realize "cost-effective and consistent yield". However, GAO points out it is "customary" for unit costs to be high in the initial production of state-of-the-art ICs. GAO found that, to correct this, DOD intends to spend \$192 million (noted in para A above) to increase the percentage of technically acceptable chips resulting from the manufacturing process (manufacturing yield), from the current range of from 0.5 percent to 2 percent up to 10 percent. This could decrease the cost per chip from as much as \$5,000 to about \$500. Noting that neither the 10 percent yield nor the \$500 per chip was derived from economic analysis, GAO questions how much yield

improvement should be funded from the VHSIC program. GAO points out that even without the \$192 million expenditure to improve yields the DOD has projected that the unit cost of VHSIC chips will decline to about \$1,500 by 1987 through contractor investments for manufacturing efficiency. GAO points out that DOD has not obtained any guarantee that the six VHSIC contractors will make any such investments on their own. Neither, GAO asserts, will these contractors guarantee any particular unit cost reduction. GAO points out that price competition has been a powerful impetus for manufacturing efficiency and price reduction in the IC industry. GAO states that over a dozen defense manufacturers have made large corporate investments--estimated at \$50 to \$100 million each--to develop their own VHSIC capabilities. GAO points out that continued funding of DOD's six VHSIC contractors may perpetuate these contractors' advantage, and could impede future competition.

DOD Nonconcur

Comment: The question of market forces raised by GAO was very seriously considered during the evolution of the yield enhancement program (and still is). It was the topic of two workshops during 1982 at which industry and government representatives discussed the various complex technical and economic issues. The conclusion of the Yield Enhancement/Manufacturing Technology workshops were that with a projected aggregate market of 1250 thousand chips in 1988 the cost per chip will be \$1,389 without yield enhancement/manufacturing technology and \$453 per chip with yield enhancement and manufacturing technology. This translates into a total DOD cost savings (with YE/MT) of \$1,170M for the year 1988 alone. The driving force, however, was the DOD need for faster availability of VHSIC technology. Commercial pressure would not do this. Therefore, the VHSIC Program Office requested the additional funds for both Yield Enhancement and Technology Insertion.

Although costs of VHSIC chips will eventually decrease because of normal market forces and experience, the advantage of accelerated use of this technology in DOD systems will be lost. Prior experience has convinced the Department's decision makers that the additional funding is absolutely necessary to accelerate the process of providing sufficient quantities of VHSIC chips at an appropriate cost for planned system use and qualification tasks. The presence of eight (six prime plus a second at TI plus subcontractor Motorola) VHSIC pilot production lines provides a strong competitive base within the VHSIC contractors. These contractors have made investments of their own corporate funds of approximately \$450 million. In addition, more than a dozen manufacturers are working toward establishing VHSIC level capabilities, largely as a result of the success of the program which translates into a total investment of \$600M by contractors not participating directly in the VHSIC program. However, few if any

of these contractors will be ready to supply VHSIC chips within the next 2 to 3 years.

DOD points out that it was only after establishment of the six VHSIC Phase 1 programs that both VHSIC and non-VHSIC contractors alike began to make large investments of their own funds to insure that they would remain competitive in the systems arena. Similarly, continued VHSIC investment on the part of DOD continues to foster even greater corporate investment. This leverage is a key aspect of the VHSIC program and any reduction in DOD funding at this time would reduce competitive pressure, slow the pace of corporate development, and delay availability of reliable VHSIC chips.

The VHSIC Phase 0 and Phase 1 procurements were competitive, thus the entire industry has been treated with fairness. The total industry outlook toward VHSIC has been largely very positive, with a constantly growing interest and activity in using VHSIC technology. The degree of tentativeness and caution being exercised by users is appropriate for any technology which is just emerging from an R&D phase.

o FINDING F: DOD Should Evaluate Effectiveness of Systems Already Funded before Subsidizing Additional Systems. GAO found that, through FY 1989, DOD plans to spend about \$148 million of VHSIC program funds as subsidies to encourage the military departments to insert VHSIC technology into 33 military programs. GAO found that the DOD Director of the VHSIC program has identified an additional requirement of \$62 million to expand such insertion beyond these programs. GAO feels that the system developer's responsibility for efficient management is strengthened where no such subsidy is used. Furthermore, accountability, including visibility of program costs to the Congress, is made more evident. In addition, GAO found that the military departments had nominated more than 100 candidate programs for VHSIC subsidies, and that VHSIC officials recognized that they did not have enough resources to subsidize all of these (at an average cost of \$4.5 million each). GAO believes that the 33 systems already sponsored by the VHSIC program could clearly demonstrate the applicability of VHSIC technology to a broad range of defense systems. GAO concludes that DOD should evaluate the effectiveness of these VHSIC system applications before subsidizing any additional system applications of first generation technology.

DOD Nonconcurs

Comment: Detailed studies of the effectiveness of VHSIC in system applications have been made since the beginning of the program, starting with a contract study by The Analytical Science Corporation (TASC). The DOD evaluated the effectiveness of the VHSIC system applications in December 1983 and followed up with insertion program reviews throughout 1984. These evaluations led to

formulation of criteria for the selection during FY84 of additional VHSIC system applications. The DOD will again evaluate all of the VHSIC system applications in January 1985. Each program candidate is thoroughly evaluated at several levels within each Service before they are approved for funding at the VHSIC program office level. Evaluations thus far have demonstrated substantial gains in capability, reliability, and maintainability. The demonstrations have been in the form of studies, preliminary designs, and brassboard demonstrations under the VHSIC development contracts. Hardware demonstrations for actual systems applications will be forthcoming in December 1984 and throughout 1985. The full impact and effectiveness of VHSIC technology can only be demonstrated when comprehensive system application programs are completed and the technology is fielded. This is one of the principle reasons for generating a comprehensive, balanced program of VHSIC system applications demonstrations through the current technology insertion efforts.

A balanced approach was one of the goals during the technology insertion process. One-third of the selectees are early insertion efforts. In nearly two-thirds of the programs, cost reductions will be realized based on system life-cycle benefits and on projected costs of the chips. Eighty-five percent of the selectees are showing performance improvements with VHSIC technology. System program office commitment has been shown for all candidates selected.

Accelerated implementation of VHSIC technology into specific systems beginning in FY85 and FY86 will require \$62.2M. The addition of this amount will constitute an effective level of VHSIC technology insertion as suggested by the DSB, and projected by the Services and the Office of the Under Secretary of Defense for Research and Engineering (OUSDRE). There are a number of Technology Insertion efforts that exploit the reliability and maintainability including built-in test aspects of the VHSIC technology. The additional request ensures that the VHSIC technology insertion effort strikes a balance in all phases of systems life cycle.

GAO ANALYSIS

DOD's comments have pointed out the need to clarify the report concerning the need for DOD to evaluate the effectiveness of VHSIC system applications before subsidizing any additional system applications of first generation technology. We did not intend, as DOD suggests, for such an evaluation to be limited to the effectiveness of individual VHSIC system applications subsidized by DOD. Instead, we were referring to an evaluation of the effectiveness of the entire technology insertion initiative in encouraging other system developers to commit to using VHSIC technology without first receiving subsidies. In appendix I, we have clearly laid out our concerns on the VHSIC technology insertion initiative.

FINDING G: DOD Should Require that Contractors' Efforts be Directed to Reducing Unit Costs. GAO found that DOD had not directed the yield enhancement effort (Finding E) to ensure that contractors focus exclusively on increasing yield and reducing cost of VHSIC chips. For example, GAO found that some of the VHSIC contractors were having problems as a result of certain features of their design or relatively large size of their chips, and would not be precluded from using yield enhancement funds to solve these problems. Also GAO states that DOD officials said these funds could be used for product improvements. GAO believes that diversion of yield improvement funds for such purposes will result in less than desired achievement in improving availability and cost of VHSIC chips. GAO concluded that DOD should place more stringent requirements on the contractors in order to ensure that the VHSIC yield enhancement efforts are as successful as possible in improving manufacturing yields and reducing unit costs.

DOD Nonconcurs

Comment: DOD does not concur that diversion of yield improvement funds to improve specific designs will have detrimental effect on availability and costs. Typically, improvements in yield of integrated circuits have been achieved through changes in circuit design and layout methodology as much as through improvement in the manufacturing process. Circuit design and layout changes can reduce the chip size and the need for tight process parameter control. Thus generic improvements in design technology, verified by application to existing chips, is an inherent part of the yield enhancement effort.

RECOMMENDATIONS

RECOMMENDATION 1: GAO recommends that the Secretary of Defense not approve the \$62 million funding requirement identified by the DOD director of the VHSIC program for additional VHSIC insertion efforts.

DOD Nonconcurs

Comment: Traditionally system developers have tended to avoid cutting-edge technology in order to eliminate risk from their programs. They have frequently used 3 to 6 year old microelectronic technology in designs which then become 10 to 15 years old when the program is fielded. This delay can only be reduced by providing the system developer with a funded VHSIC based alternative. Nevertheless, it is expected that the use of VHSIC technology will provide substantial benefits to DOD systems that increased funding to allow additional systems the benefit of evaluating VHSIC will be money very well spent. Further, the added customer support provided by the technology insertion funding will create more competition at the system level; thus this represents a highly leveraged investment.

o RECOMMENDATION 2: GAO recommends that the Secretary of Defense make continued yield enhancement funding contingent on each contractor's demonstration of progress toward meeting the 10 percent yield and \$500 unit cost goals by 1987.

DOD Concurs

Comment: The \$192M allocated for this effort consists of \$102M for yield enhancement and \$90M for manufacturing technology. Under the framework of the existing VHSIC Phase 1 contracts, objective yield enhancement progress goals, consistent with the 10 percent goal, will be established by February 1985, and progress payments will be made based upon attaining these goals. The manufacturing technology program contracts will be awarded in FY85. The work statements for these contracts will contain yield objectives upon which progress payments will be made where applicable.

o RECOMMENDATION 3: GAO recommends that the Secretary of Defense require that DOD yield enhancement funds be used exclusively for improvements in the manufacturing efficiency of VHSIC chips in general, and not on problems that are unique to individual VHSIC chips or on product improvements.

DOD Nonconcur

Comments: The yield of a product going through a production line is a function of both the processes used by the line and the detailed design of the chip. The intent of the VHSIC Program Office and the wording of the yield enhancement contracts is to put the major emphasis, and attention to, the inherent capability of the line. As stated above (ref. Finding G), it is standard practice within the integrated circuit industry to alter circuit designs to be compatible with the process and device parameters evolving on a maturing pilot line. Improved circuit design and layout methodology are inherent parts of a yield enhancement effort. Minor design rule changes which make the chip manufacturable at higher yield in that line should not be excluded, however. These circumstances are under the control of the DOD. Prohibition of improvement of specific circuits would unnecessarily restrict the progress of the yield enhancement program.

GAO ANALYSIS

Considering DOD's concurrence in recommendation 2, DOD's recognition that VHSIC chip design changes will be necessary, and DOD's assuming control of such design changes, we believe that the chance of the VHSIC contractors' diverting yield enhancement subsidies to other than generic design and manufacturing improvement will be minimized. Therefore, we have decided not to pursue recommendation 3.

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